Behavioral and chemical ecology in British Columbia

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Behavior can be broadly defined as the response of an individual to a change in its environment. During the past 50 years many ESBC members have studied insect behavior both directly and indirectly. Below we chronicle two major schools of behavior, (1) basic studies and (2) research on aspects of pheromone production and response.

Behavior studies are represented in almost every volume of the past 50 issues of JESBC yet they are never common. In fact, excluding the pheromone-based studies, papers that deal directly with behavior make up just 6% (27/452) of all the papers published between the years 1968 and 2000. This low frequency may not be unique to JESBC. A survey of The Canadian Entomologist between 1980 and 1983 gives a nearly identical frequency of behavior-based papers (29/505).

Our survey focuses on papers that study behavior for its own sake. Many other papers have behavioral components or evaluate phenomena that are driven by behavior (e.g. trap captures - Vernon and Gillespie 1990). Either way, behavior-based studies that are published in the JESBC are drawn from a wide variety of insect taxa including, Hempitera, Homoptera, Thysanoptera, Hymenoptera, Diptera, Lepidoptera and Coleoptera. The topics range from oviposition preference in pear psylla (Stuart *et al.* 1989) to predator avoidance in fireworms (Fitzpatrick *et al.* 1994).

Behavioral ecology

There are five significant developments during the past fifty years in behavioral entomology in British Columbia. First, in the mid-1960s, Bill Wellington and C.S. (Buzz) Holling arrived at the University of British Columbia (UBC) from the Canadian Forest Service. Wellington's studies on the maternal effects on the behavior of forest caterpillars are classic while Holling's derivation (Holling 1966) of the functional response has spawned a veritable cottage industry. Additional UBC faculty with behavior based programs include, Ken Graham (behavior of bark beetles), Geoff Scudder (behavior of various hemipterans), Judy Myers (behavior underlying population processes), Bob Elliot (grasshopper feeding), Murray Isman (impact of natural products on insect feeding), John McLean (behavior of forest insects) and Bill John Richardson (behavior of aquatic insects).

The second major development was the formation of the Pestology Centre at Simon Fraser University (SFU) in 1967. Several members of the centre focused on behavior including, Bert Turnbull (predators), John Borden (host and mate-seeking behaviors), Peter Belton (acoustic and oviposition behaviors in mosquitoes), Manfred Bryan Beirne (behavior of biocontrol agents). Later additions to this group were Mark Winston (bee behavior), Bernie Roitberg (behavioral ecology) and Gerhard Gries (pheromone-based behaviors).

Third, the development of technology for identifying and synthesizing insect pheromones has had tremendous impact on research programs at BC universities and government research stations. A detailed history is provided below.

Fourth, the Behavioural Ecology Research Group (BERG) was established at SFU in the mid 1980s. Several members of the BERG used principles from evolutionary biology to study behavior of a range of organisms. These individuals include Bernie Roitberg,

Mark Winston, Bernie Crespi (thrips), Larry Dill (aphids, phantom midge larvae and water striders) and Ron Ydenberg (bees).

Fifth, the 1990s will be remembered for the awakening of the biodiversity consciousness in this province. Led by Geoff Scudder and Richard Ring, the habits of lesser known and endangered species were studied in their native habitats. Of particular concern was the issue of habitat fragmentation and its impact on insect colonization and perpetuation. To get a handle on these important issues requires a good understanding of how insect behavior shapes habitat use.

Finally, behavior has featured in the research programs at government labs throughout the province (Table 1). In many cases, there has been a conscious attempt to link behavior to pest population dynamics. This approach is exemplified by Bryan Frazer and Neil Gilbert's (1976) seminal studies on the role of predator and prey behavior in the

Table 1

Government scientists and university researchers who have worked on insect behavior in British Columbia but were not mentioned by name above.

NAME	AFFILIATION	STUDY ORGANISM OR AREA OF STUDY
Nello Angerilli	Agriculture Canada	Orchard pests
Brad Anholt	U Victoria	Aquatic insects
Rene Alfaro	Forestry Canada	Forest insects
Robb Bennett	Ministry of Forests	Forest insects
Gerry Carlson	Phero Tech Inc	Forest insects
Alan Caroll	Forestry Canada	Forest insects
Joan Cossentine	Agriculture Canada	Orchard pests
Bob Costello	BC Government	Mosquitoes, greenhouse insects
Collin Curtis	Agriculture Canada	Mosquitoes
Don Elliott	Private	Parasites, predators
Doug Finlayson	Agriculture Canada	Root maggots
Henry Gerber	BC Government	Bees, wasps
Linda Gilkeson	BC Government	Biocontrol
David Gillespie	Agriculture Canada	Parasitoids, greenhouse insects
Jack Gregson	Agriculture Canada	Ticks
Staffan Lindgren	U Northern BC	Forest insects
Deborah Henderson	Private	Parasites, predators
Leland Humble	Forestry Canada	Forest insects
HR (Mac) MacCarthy	Agriculture Canada	Aphids
Dave McMullen	Agriculture Canada	Orchard pests
Lorraine Maclauchlan	Forestry Canada	Forest insects
Vince Nealis	Forestry Canada	Forest insects
Imre Otvos	Forestry Canada	Forest insects
David Raworth	Agriculture Canada	Insect predators
Les Safranyik	Forestry Canada	Forest insects
Ward Strong	Ministry of Forests	Forest insects
Robert Traynier	BC Research	Mosquitoes, turf pests
Fred Wilkinson	Agriculture Canada	Wireworms, biocontrol
Jerry Weintraub	Agriculture Canada	Warble flies
Paul Wilkinson	Agriculture Canada	Ticks
Ian Wilson	Phero Tech Inc	Forest insects
Neville Winchester	U Victoria	Tree canopy insects
Bob Wright	BC Research	Mosquitoes

population dynamics of pea aphids. In the next section, we discuss the role of behavior in chemical ecology studies on insect pests.

Chemical ecology

Studies in insect chemical ecology are devoted to promoting an ecological understanding of the origin, function, and significance of semiochemicals (message-bearing chemicals) that mediate interactions within and between organisms. Such relationships, often adaptively important, comprise the oldest and likely most prevalent communication systems in terrestrial and aquatic environments.

Research in Chemical Ecology in British Columbia began in the 1960s when Ken Graham (1968) at UBC explored the primary attraction of ambrosia beetles to Douglas-fir logs undergoing anaerobic metabolism. This research culminated in 1970 with the discovery by Henry Moeck of the Pacific Forestry Center (PFC, Victoria) that ethanol was the compound responsible for this phenomenon. Another pioneer was John Chapman (1966) of PFC who demonstrated in 1966 that a pheromone produced by female striped ambrosia beetles, *Trypodendron lineatum* (Olivier), was responsible for mediating secondary attraction to and mass attack of host logs.

Since the arrival of John Borden at SFU in 1966, studies in insect chemical ecology have been closely linked with, but not restricted to, faculty members at SFU. In 1981, interdisciplinary research in chemical ecology was formalized by establishing the Chemical Ecology Research Group (CERG) comprised of the entomologist John Borden, chemists Keith Slessor and Cam Oehlschlager, apiculturist Mark Winston and plant pathologist Jim Rahe. In 1992 Gerhard Gries joined the group. Group members have specialized on identification and development of pheromones to manipulate economically important insects in forestry, agriculture and stored products.

The list of achievements by CERG members is long and impressive. Particularly significant are the identification of bark and ambrosia beetle pheromones and their strategic deployment to alleviate the beetles' economic impact (Borden and McLean 1981; Borden 1990). Major accomplishments by CERG members and their students also include the identification of the honey bee queen's mandibular gland pheromone (Slessor *et al.* 1988), elucidation of pheromone biosyntheses (Plettner *et al.* 1996) and deployment of synthetic pheromone to manipulate the bees' behavior within and outside the hive (Winston and Slessor 1992). Gerhard and Regine Gries have used coupled gas chromatographic-electroantennographic detection (GC-EAD) techniques to identify new pheromones and kairomones for many insects, including the exotic orange wheat blossom midge (Gries *et al.* 2000).

Two 'semiochemical companies' are spin-offs of CERG's research activity. Phero Tech Inc., founded by SFU graduates in 1981, launched its commercial enterprise by offering a pheromone-based management program for ambrosia beetles. Today, Phero Tech offers a wide variety of semiochemical products, traps and services for North American and world-wide markets. Phero Tech Inc. also provides first employment for many graduates of the Master of Pest Management program at SFU. ChemTica Internacional, founded by Cam Oehlschlager and his wife Lilliana Gonzales in 1991 in Costa Rica, started out by marketing pheromones of palm weevils and rhinoceros beetles identified in CERG's laboratories. Like Phero Tech Inc., ChemTica now offers diverse semiochemical products, particularly in tropical regions.

Following the pioneering work of Chapman and Moeck, government-based scientists have also developed considerable expertise in the chemical ecology of insect pests in forestry and agriculture. In one of the earliest applications of GC-EAD technology (Struble and Arn 1984), Dean Struble (Agriculture Canada, Lethbridge Research Station) elucidated a number of lepidopteran pheromones. Roy Sheperd and Tom Gray of PFC

(1985) developed synthetic moth pheromones as a tool to monitor population densities of lepidopteran forest defoliators and to determine incipient outbreaks. Mike Hulme and Tom Gray of PFC (1994) successfully used pheromone-based mating disruption to control an infestation of the Douglas-fir tussock moth. Research by Sheila Fitzpatrick *et al.* (1998) of the Pacific Agri-Food Research Centre (PARC, Agassiz) on pheromone-based control of the blackheaded fireworm, a pest of cranberry, lead to 3M Canada's registration of the pheromone by the Pest Management Regulatory Agency. Gary Judd of PARC (Summerland) developed a research program aimed at integrating semiochemicals into orchard IPM systems and deciphering the mechanisms mediating pheromone-based insect control (e.g. Judd *et al.* 1997; Evenden *et al.*, 2000). Most recently, Bob Vernon of PARC (Agassiz) has implemented a mass-trapping program for the European wireworm in the Fraser Valley in an ambitious effort to save the local potato growing industry.

Current and future research by ESBC members in the fields of behavioral and chemical ecology of insects will continue to advance our basic knowledge about insects and to improve management of pest insects in commercial settings.

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REFERENCES

Borden, J.H. 1990. Use of semiochemicals to manage coniferous tree pests in western Canada. Pp. 281-314 In: R.L. Ridgeway, R.M. Silverstein and M.N. Luscoe (Eds.), Behaviour-modifying chemicals for insect management: application of pheromones and other attractants. Marchel Dekker, New York.

Borden, J.H. and J.A. McLean. 1981. Pheromone-based suppression of ambrosia beetles in industrial timber processing areas. Pp. 133-154 In: E.R. Mitchell (Ed.) Management of insect pests with semiochemicals. Plenum Press, New York.

Chapman, J.A. 1966. The effect of attack by the ambrosia beetle, *Trypodendron lineatum* (Olivier) on log attractiveness. The Canadian Entomologist 98: 50-59.

Evenden, M.L., G.J.R. Judd and J.H. Borden. 2000. Investigations of mechanisms of pheromone communication disruption of *Choristoneura rosaceana* (Harris) in a wind tunnel. Journal of Insect Behavior 13: 499-510.

Fitzpatrick, S., J. Troubridge and C. Maurice. 1994. Parasitoids of blackheaded fireworm (*Rhopobota naevana* Hbn.) larvae on cranberries, and larval escape behaviour. Journal of the Entomological Society of British Columbia 91: 73-74.

Fitzpatrick, S.M., J.T. Troubridge and C. Maurice. 1998. Pheromone-mediated mating disruption as a pest management strategy for *Rhopobota naevana* Hubner, the blackheaded fireworm of cranberries. Second International Symposium on Insect Pheromones in Wageningen, The Netherlands.

Frazer, B.D. and N. Gilbert. 1976. Coccinellids and aphids: A quantitative study of the impact of adult ladybirds (Coleoptera: Coccinellidae) preying on field populations of pea aphids (Homoptera: Aphididae). Journal of the Entomological Society of British Columbia 73: 33-56.

Graham, K. 1968. Anaerobic induction of primary chemical attractancy for ambrosia beetles. Canadian Journal Zoology 46: 905-908.

Gries, R., G. Gries, G. Khaskin, G.G.S. King, O. Olfert, L.-A. Kaminski, R. Lamb, I. Wise and R. Bennett. 2000. Sex pheromone of the orange wheat blossom midge, *Sitodiplosis mosellana*. Naturwissenschaften 87: 450-454.

Holling, C.S. 1966. The functional response of invertebrate predators to prey density. Memoirs of the Entomological Society of Canada 48: 1-86.

Hulme, M. and T. Gray. 1994. Mating disruption of Douglas-fir tussock moth (Lepidoptera: Lymantriidae) using a sprayable bead formulation of (Z)-6-heneicosen-11-one. Environmental Entomology 23: 1097-1100.

Judd, G.J.R., M.G.T. Gardiner and D.R. Thompson. 1997. Control of codling moth in organically-managed apple orchards by combining pheromone-mediated mating disruption, post-harvest fruit removal and tree banding. Entomologica experimentalis et applicata 83:137-146.

Moeck, H.A. 1970. Ethanol as the primary attractant for the ambrosia beetle, *Trypodendron lineatum* (Coleoptera: Scolytidae). The Canadian Entomologist 102: 985-995.

Plettner, E., K.N. Slessor, M.L. Winston and J.E. Oliver. 1996. Caste-selective pheromone biosynthesis in honeybees. Science 271: 1851-1853.

Shepherd, R.F., T.G. Gray, R.J. Chorney and G.E. Daterman. 1985. Pest management of Douglas-fir tussock moth: monitoring endemic populations with pheromone traps to detect incipient outbreaks. The Canadian Entomologist 117: 839-848.

Slessor, K.N., L.-A. Kaminski, G.G.S. King, J.H. Borden and M.L. Winston. 1988. Semiochemical basis of the retinue response to queen honey bees. Nature 332: 354-356.

Struble, D.L. and H. Arn. 1984. Combined gas chromotography and electroantennogram recording of insect olfactory responses. Pp. 161-178 In: H.E. Hummel and T.A. Miller (Eds.), Techniques in pheromone research. Springer-Verlag, New York.

Stuart, L., B. But and R. Bell. 1989. Effect of host phenology on ovipositional preference of winter form pear psylla (Homoptera: Psyllidae). Journal of the Entomological Society of British Columbia 86: 34-38.

Vernon, R.S. and D.R. Gillespie. 1990. Responses of *Frankliniella occidentalis* and *Trialeurodes vaporariorum* to fluorescent traps in cucumber greenhouses. Journal of the Entomological Society of British Columbia 87: 38-41.

Winston, M.L. and K.N. Slessor. 1992. An essence of royalty: honey bee queen pheromone. American Scientist 80: 347-385.